P. 39 (3)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 March 2001 (29.03.2001)

PCT

(10) International Publication Number
WO 01/22413 A1

(51) International Patent Classification[7]: G11B 7/24, 7/26, 23/28, 7/013, 7/125

(21) International Application Number: PCT/IB99/01578

(22) International Filing Date: 24 September 1999 (24.09.1999)

(25) Filing Language: English

(26) Publication Language: English

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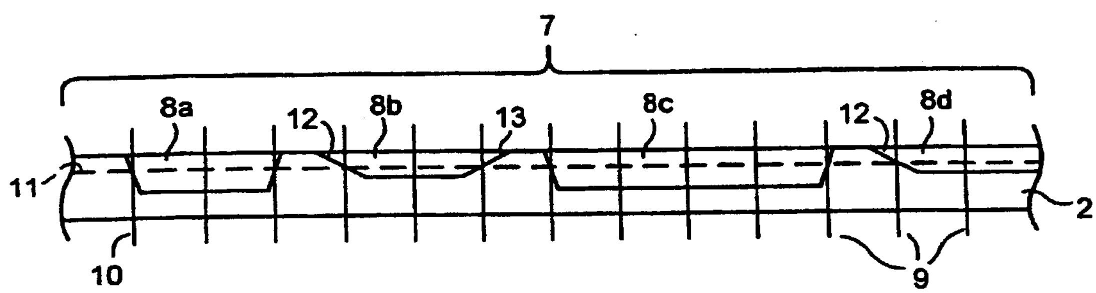
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OPTICALLY READABLE DATA CARRIER AND MANUFACTURE THEREOF



(57) Abstract: In order to produce an optical data carrier (1) with a visible image (7) in its data bearing portion, a proportion of the data pits (8b, 8d) are reduced in depth. Under normal circumstances, the reduction in depth is limited because excessive jitter is introduced in the signal read from such a carrier. To solve this problem, a writing beam is modulated so as to extend the shallower pits or to ensure that the lead-in and lead-out slopes of the shallower pits are the same as those of the deeper pits.

WO 01/22413 A1

Optically Readable Data Carrier and Manufacture Thereof

Field of the Invention

The present invention relates to an optically readable data carrier, master therefore, a mastering apparatus and a method of forming a master.

Background to the Invention

Software, including computer programs, music and videos, is increasingly being published in the form of optically readable data carriers such as CDs, CD-ROMs and DVDs. A major problem facing publishers of software in these formats is the ease with which their products can be counterfeited. The data on the carriers can be read error-free and then used to create new masters using conventional equipment. The resultant counterfeit products are very difficult, if not impossible, for the publisher's agents and law-enforcement officials to identify.

US-A-5398231 discloses an optical disk in which a visible image is formed in the recording region by producing pits that are deeper and wider than the pits representing the recorded data. While this patent explains that data can be recorded in the area where the image is formed, the pits forming the image are not themselves involved in the storage of data. Thus, the capacity of the data carrier is reduced by the presence of the image.

EP-A-0810593 discloses an optical disk in which data pits are modified to produce an observable image. However, the modifications are very small and the modified pits still fall within the tolerances specified for the particular type of data carrier. Consequently, the contrast that can be achieved in the image is limited. EP-A-0810593 also discloses a method of manufacturing a master for image bearing optical disks. The method involves placing a plate below the master during scanning of a photoresist layer with a laser. The plate has a pattern of reflective and non-reflective regions and photoresist areas above reflective areas receive an extra dose of light, i.e. light reflected from the plate back through the master's substrate, during scanning. These areas then produce larger pits in the master and ultimately disks produced using the master.

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Summary of the Invention

It is an object of the present invention to provide an optically readable data carrier in which an image with improved contrast is formed in a recording region without interrupting the sequence of data storage pits.

According to the present invention, there is provided an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits has a substantially flat region whose depth is less than 86% of the depth of the pits which are not in the subset, so as to produce an observable image. Preferably, the depth of said region is in the range 70% to 80% of the depth of the pits that are not in the subset.

The pits of said subset may be longer than would be the case if they were not members of the subset. In this context, the length of the pit is the distance from its very start to its very end, not the distance between the data state transition decision points.

According to the present invention, there is also provided an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits is of lesser depth and is longer than would be the case if it were not a member of the subset.

Preferably, the profiles of the pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame. This allows for the gentler lead in and lead out slopes that would be produced if the master were to be prepared by using reduced laser power to define the pits of the subset. Consequently, the data carrier, for instance a CD, can be read by conventional consumer equipment. Still more preferably, said timebase frame is configured for constant linear velocity reading of data stored by said pits.

Preferably, a data carrier according to the present invention comprises a disc-shaped substrate. However, the present invention is not limited in its application to disc-shaped data carriers.

According to the present invention, there is also provided an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits has a substantially flat shallower intermediate region between start and end regions of greater depth..Preferably, the depth of each said intermediate region is in the range 70% to 80% of the depth of the associated start and end regions.

Preferably, in each case, the observable image is visible to the naked eye because counterfeit data carriers can then be detected without special equipment. However, the image could be one that can only be viewed under a microscope or under special lighting conditions.

According to the present invention, there is also provided a master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits has a substantially flat region whose depth is less than 86% of the depth of the pits which are not in the subset, so as to produce an observable image on an optical data carrier manufactured with the master. Preferably, the depths of said regions are in the range 70% to 80% of the depth of the pits which are not members of the subset.

Preferably, the observable image is visible to the naked eye.

Preferably, the profiles of the data storage pit mastering pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

Preferably, the pits of said subset are longer than would be the case if they were not members of the subset.

Preferably, said timebase frame is configured for constant linear velocity reading of data stored by pits formed using the data storage pit mastering pits.

According to the present invention, there is also provided a master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits is of lesser depth and is longer than would be the case if it were not a member of the subset.

Preferably, the observable image is visible to the naked eye.

Preferably, the profiles of the data storage pit mastering pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

Preferably, said timebase frame is configured for constant linear velocity reading of data stored by data storage pits formed using said data storage pit mastering pits.

According to the present invention, there is also provided a master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits has a substantially flat shallower intermediate region between start and end regions of greater depth. Preferably, the depth of each said intermediate region is in the range 70% to 80% of the depth of the associated start and end regions.

Preferably, the observable image is visible to the naked eye.

According to the present invention, there is also provided a optical data carrier mastering apparatus comprising: a source of digital data signals; a source of image data signals; signal processing means for modifying a digital data signal from the source of digital data signals in dependence on an image data signal from the source of image data signals; and a beam device responsive to the output of the signal processing means and arranged for scanning a master with a beam, wherein the signal processing means selectively modifies

the digital data signal so as to reduce the intensity of the beam during formation of pits representing both said digital data and said image data.

Preferably, the signal processing means is responsive to an image data signal from the source of image data signals to extend the duration of pits representing both said digital data and said image signals.

Preferably, the signal processing means comprises: a variable delay for delaying digital data signals from the source of digital data signals, a pulse extending circuit for selectively extending delayed digital data pulses output by the variable delay, and a pulse amplitude control circuit for controlling the amplitude of digital data pulses output by the pulse extending circuit, wherein the variable delay is responsive to image data signals at first level to introduce a first delay and to image data signals at a second level to introduce a second smaller delay, the pulse extending circuit is responsive to image data signals at said second level to extend digital data pulses, and the amplitude control circuit is responsive to image data signals being at said second level to output pulses for producing a beam of reduced intensity.

Preferably, the signal processing means is responsive to an image data signal from the source of image data signals to produce an internal region of reduced depth in pits representing both said digital data and said image signals.

Preferably, the signal processing means comprises: a first delay for delaying digital data signals from the source of digital data signals, a second delay for delaying delayed digital data signals output by the first delay; an AND-gate for ANDing the outputs of the source of digital data signals, the source of image data signals, the first delay and the second delay, and a modulator for modulating the amplitude of the output of the first delay with the output of the AND-gate to generate a driving signal for the beam device.

Preferably, the beam device comprises a laser.

According to the present invention, there is also provided a method of forming a master for an optical data carrier bearing an observable image, the method comprising the steps of:-

providing a digital data signal;

providing an image data signals

modifying the digital data signal in dependence on the image data signal to produce a modified digital data signal; and

irradiating a master blank in dependence on the modified digital data signal using a beam for forming a pattern of pits,

wherein pulses of the digital data signal is selectively modified so as to reduce the intensity of the beam during formation of pits representing both said digital data and said image data.

Preferably, the digital data signal is modified so as to lengthen pits formed using said reduced intensity.

Preferably, the digital data signal is modified so as to reduce the intensity of the beam only during formation of intermediate portions of pits representing both said digital data and said image data

Brief Description of the Drawings

Figure 1 is a plan view of an optical disk according to the present invention;

Figure 2 is a sectional view of a first optical disk according to the present invention;

Figure 3 is a partial sectional view of the substrate of the optical disk of Figure 2 in which the pit depths have been exaggerated so as to illustrate the present invention more clearly;

Figure 4 is a block diagram of a first disk-mastering apparatus according to the present invention;

Figure 5 is a circuit diagram of the delay buffer of Figure 4;

Figure 6 is a circuit diagram of the duty cycle modulator of Figure 4;

Figure 7 is a block diagram of the image data source of Figure 4;

Figure 8 is a flowchart illustrating the generation of image data;

Figure 9 is a flowchart illustrating the operation of the image data source of Figure 4;

Figure 10 is a circuit diagram of the image data transition inhibiting circuit of Figure 4;
Figure 11 is a waveform diagram illustrating the control of the laser of Figure 4 during mastering of an image region;
Figure 12 is a partial sectional view of an image region of the substrate of a second optical disk according to the present invention in which the pit depths have been exaggerated so as to illustrate the present invention more clearly;
Figure 13 is a block diagram of a second disk-mastering apparatus according to the present invention;
Figure 14 is a circuit diagram of the delay buffer of the disk-mastering apparatus of Figure 13;
Figure 15 is a circuit diagram of the modulation signal generator of Figure 13;
Figure 16 is a circuit diagram of the modulator of Figure 13; and
Figure 17 is a waveform diagram illustrating the control of the laser of Figure 13 during mastering of an image region.

Description of the Preferred Embodiments

Preferred embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings.

Referring to Figures 1 and 2, an optical disk 1 comprises a disc-shaped substrate 2 which is coated on one face with a reflective layer 3. The coated surface of the substrate 2 is pitted in a recording region 4 and the reflective layer 3 conforms to the pits in the substrate 2. A transparent protective layer 5 overlies the reflective layer 3. A hole 6 for receiving a spindle of a playback apparatus is centrally located in the disk 1.

The pits in the substrate 2 are modified, in a manner to be described below, in an image area 7 to produce a visible image.

Referring to Figure 3, "1"s of the digital data stored on the optical disk 1 are represented by the transitions at the beginnings and ends of first, second, third and fourth pits 8a, 8b, 8c, 8d. "0"s are represented by the lack of such transitions. Accordingly, the transitions must coincide with timebase reference points 9 of a timebase frame. Thus, starting at point 10, the data represented in Figure 3 is 1011011000110....

It can be seen that the first and third pits 8a, 8c are deeper and wider than the second and fourth pits 8b, 8d. However, all of the pits 8a, 8b, 8c, 8d extend below a decision depth 11 which is the depth that produces a reflected signal taken to be the transition between a pit and a land. The second and fourth pits 8b, 8d are not only shallower than the first and second pits 8a, 8c, their lead in and lead out slopes 12, 13 are less steep. Consequently, in order for the decision depth to be reached at the correct time, their lead in and lead out slopes 12, 13 start earlier and finish later than would otherwise be the case.

It is the difference in the pit depths and widths that produces the observable image in the image area 7.

A mastering apparatus for producing an optical disk 1 as shown in Figure 3 will now be described.

Referring to Figure 4, an optical disk mastering apparatus comprises a source 20 of data signals representing, for example, music or a computer program, a delay buffer 21 connected to receive data signals from the source 20 of data signals, a duty cycle modulator 22 connected to receive the data signals from the delay buffer 21, a laser 23 arranged to focus a writing laser beam 24 onto a master 25, a drive system 26 for rotating the master substrate 25 and outputting a tacho signal to an image data source 27 which outputs image signals via an image signal transition inhibiting circuit 29 to an inhibit input of the delay buffer 21 and an enable input of the duty cycle modulator 22, and an amplifier 28 that receives the outputs of the duty cycle modulator 22 and the image signal transition inhibiting circuit 29 as inputs and whose output is applied as a control signal to the laser 23. The image signal transition inhibiting circuit 29 serves to prevent the image signals changing state during pit formation.

Referring to Figure 5, the delay buffer 21 has at its core a first D-type flip-flop 30. The clock signal for the first D-type flip-flop 30 is generated from the input data signal by first to fifth inverters 31, 32, 33, 34, 35, a two-input exclusive-OR gate 36, and a first, '123 type monostable multivibrator 37. A first resistor 38 and a first capacitor 39 define

the default output pulse width of the first monostable multivibrator 37. The first, second and third inverters 31, 32, 33 are connected in series and the incoming data is applied first to the input of the first inverter 31. The output of the third and fourth inverters 33, 34 are connected to respective inputs of the exclusive-OR gate 36. The input of the fourth inverter 34 is connected to the node between the first and second inverters 31, 32. The fifth inverter 35 is connected to receive the output of the exclusive-OR gate 37 and its output is connected to the input of the first monostable multivibrator 37. The Q output of the first monostable multivibrator 37 is connected to the clock input of the flip-flop 30. The output of the first inverter 31 is also connected to the D input of the flip-flop 30.

The inhibit input is coupled to the input of a sixth inverter 40 whose output is coupled to the input of a seventh inverter 41. The output of the seventh inverter 41 is connected to the anode of a first diode 42. The cathode of the first diode 42 is connected to one end of a variable resistor 43. The other end of the variable resistor 43 is connected to the node between the first resistor 38 and the first capacitor 39.

As a result of extra delay introduced by the extra inverter 33 in one input path to the exclusive-OR gate 37, the exclusive-OR gate 37 outputs a short positive-going pulse or spike each time the input data changes logic level. The short pulse is inverted by the fifth inverter 35 causing the output of the fifth inverter 35 to approach ground, thereby triggering the first monostable multivibrator 37. The first monostable multivibrator 37 then outputs a positive-going pulse at its Q output. If the inhibit input is at logic "0", the length of the pulse is determined by the first resistor 38 and the first capacitor 39. However, if the inhibit input is at logic "1", the first capacitor 39 is additionally charged through the variable resistor 43. Thus, the charging time for the first capacitor 39 is reduced when the inhibit input is a logic "1" and the pulse output by the first monostable multivibrator 37 is shorter. The negative-going edge of the output pulse of the first monostable multivibrator 37, clocks the flip-flop 30 transferring the logic level on its D-input to its Q output.

It can be seen therefore that the first monostable multivibrator 37, the first capacitor 39, the first resistor 38, the sixth and seventh inverters 40, 41, the first diode 42 and the

variable resistor 43 comprise a variable delay circuit for the first D-type flip-flop's clock; the delay being switchable between a first value t_0 and a second value t_1, where $t_1 - t_0$ = difference in the start times for the first and second pits 8a, 8b relative to their respective nearest timebase reference positions 9, typically in the region of 50ns for conventional 1 x CD recording depending on the modulation depth used. The first diode 42 is present so that there is not a discharge path through the variable resistor 43 for the first capacitor 39 when the inhibit input is at logic "0".

The Q output of the flip-flop 30 is connected to one terminal of a second capacitor 45 and to the non-inverting input of a differential amplifier 46. The other terminal of the second capacitor 45 is connected to ground. The inverting input of the differential amplifier 46 is connected to the wiper of a potentiometer 47 connected between the positive supply Vcc and ground. The output of the differential amplifier 46 is connected to the input of an eighth inverter 48 via a second resistor 49. The input of the eighth inverter 48 is protected against negative voltages by a second diode 50 connected between its input and ground.

The second capacitor 45, the differential amplifier 46 and the potentiometer 47 provide means for ensuring that the output delayed data signal has the correct mark-space ratio.

Referring to Figure 6, the duty cycle modulator 22 comprises of second monostable multivibrator 58 functionally equivalent to the '4538 type. The durations of the pulses produced by the second monostable multivibrator 58 are set by a third resistor 51 and a third capacitor 52. The reset terminal of the second monostable multivibrator 58 is connected to the positive supply Vcc via a fourth resistor 53. The enable input is connected to the A-input of the second monostable multivibrator 58 via a ninth inverter 54. The delayed data input is connected to the B input of the second monostable multivibrator 58. In this configuration, the second monostable multivibrator 58 outputs a positive-going pulse at its Q output on a falling edge of the delayed data signal from the delay buffer 21,when the enable input is at logic "1". Thus, a pulse is output in association with the end of each pulse that will be used to form a shallow pit.

The delayed data input is also connected to one input of a two-input OR-gate 55 via tenth and eleventh inverters 56, 57. The other input of the OR-gate 55 is connected to the Q output of the second monostable multivibrator 58. The OR-gate 55 adds the pulses from the second monostable multivibrator 58 to the ends of respective delayed data pulses to extend them. The tenth and eleventh inverters 56, 57 are provided to introduce a small delay to ensure that the transitions between the delayed data pulses and the added pulses are seamless. The duration t_e of the pulses output by the second monostable multivibrator 58 is equal to $t_0 - t_1 + t_k$, where t_k is the difference between the delay introduced by the eleventh and twelfth inverters 56, 57 and the delay between triggering of the second monostable multivibrator 58 and the start of its output pulse.

Referring to Figure 7, the image data source 27 comprises a microcomputer 60, an interface unit 61 coupled to the microcomputer 60, a crystal oscillator 62, a divide-by-N circuit 63 for dividing the output of the crystal oscillator 62 and a synchronising circuit 64. The interface unit 61 is coupled to the synchronising circuit 64 by a DATA line, a STROBE line, an ALERT line and a BUSY line. The interface unit 61 also receives the tacho signal from the drive system 26. The tacho signal comprises one pulse be revolution of the master 25 and each pulse is generated at the same angular position of the master 25. The synchronising circuit 64 also receives the output of the divide-by-N circuit 63. The frequency of the signal output by the divide-by-N circuit 3 defines the resolution of the image to be formed. The N value can be changed depending on the resolution that is desired. However, it must be set so that the image is properly distributed across the disk.

Communication between the interface unit 61 and the synchronising circuit 64 is similar to that employed by "Centronics" parallel ports. The DATA and ALERT lines correspond to two of the DATA lines of the "Centronics" parallel port.

Internally, the synchronising circuit comprises an AND-gate 65 whose inputs are connected to the STROBE line and the output of the divide-by-N circuit 63, a second D-type flip-flop 66 and a SR flip-flop 67. The D input of the second D-type flip-flop 66 is coupled to the DATA line and the clock input of the D-type flip-flop 66 is coupled to the output of the AND-gate 65. The set input of the SR flip-flop 67 is coupled to the

ALERT line and the reset input of the SR flip-flop 67 is coupled to the output of the AND-gate 65.

The generation of the image data will now be described with reference to Figure 8. Unless a particular element is identified, it is to be assumed that a step is performed by the microcomputer 60 under program control with reference to input commands.

Referring to Figure 8, a bitmap file containing the image to be formed on an optical disk is first selected (step s1). The bitmap is of a black and white image, i.e. 1 bit per pixel, because colour information would be redundant. However, halftone and grey-scale images can be formed by processing an so that different tones are expressed by different densities of "black" dots, lines or the like.

The image defined by the bitmap file must be mapped onto the spiral track structure of the optical disk to be produced. To achieve this, the bitmap is sampled along a plurality of concentric circular paths (step s2) (these paths approximate the spiral track pattern of a CD). The number of samples taken along the circles is a function of the radius of the current circle in accordance with the constant linear velocity recording method used for CDs. The resultant data is output (step s3) as a file comprising a sequence of bits for each circle, separated by line end codes. CD's are recorded from the middle out. Therefore, the sequences of bits become longer through the file.

Referring to Figures 7 and 9, during exposure of the master 25, the microcomputer 60 loads the file produced at step s3. On receiving a tacho pulse (step s12), the microcomputer 60 gets the next data bit (step s13) and applies it to the DATA line and simultaneously applies a pulse to the ALERT line (step s14). The pulse on the ALERT line sets the SR flip-flop 67 signalling the busy state on the BUSY line. Once the data has been output, the microcomputer 60 outputs a pulse on the STROBE line (step s15). When the next pulse from the divide-by-N circuit 63 arrives, the AND-gate 65 outputs logic "1" which clocks the data from the D input of the second D-type flip-flop 66 to its Q output. The output of the AND-gate 65 also resets the SR flip-flop 67, signalling not busy on the BUSY line.

When the microcomputer 60 detects the not busy signal on the BUSY line, it determines whether it has reached the end of the image data file (step s17). If the end has been reached, the program is exited. If the end of the file has not been reached, the microcomputer 60 checks for an end of line marker (step s18). If the end of line marker is not detected, the flow of the program returns to step s14. Otherwise, the microcomputer 60 repeatedly outputs the last data bit, and accompanying alert and strobe signals (steps s19, s20 and s21), until a tacho pulse is received (step s22). If a tacho pulse is received, the flow of the program returns to step s13.

For applications in which the image is to be viewed with the naked eye, the image data for each "circle" will be used for a plurality of consecutive revolutions of the master 25 because the width of the track of a CD is far smaller than the pixel size necessary.

Referring to Figure 10, the image signal transition inhibiting circuit 29 comprises a third D-type flip-flop 70, twelfth, thirteenth and fourteenth series-connected inverters 71, 72, 73. The D input of the third D-type flip-flop 70 is coupled to the output of the image data source 27 and its clock input is connected to the output of the fourteenth inverter 73. The input of the twelfth inverter 71 is coupled to the output of the duty cycle modulator 22. Consequently, the output of the third D-type flip-flop 70 cannot change state while a pit is being recorded and can only change during land periods. The use of three inverters in series introduces a small delay that provides a small guard region between the ends of pits and image data transitions.

The control of the laser of 23 will now be described. With regard to the following description, it is to be understood that the master 25 is being rotated by the drive system 26 and the laser beam 24 scanned radially in the conventional manner.

Referring to Figures 4 and 11, Figure 11(a) shows the output of the image data source 27, Figure 11(b) shows the output of the image signal transition inhibiting circuit 29, Figure 11(c) shows the output of the data source 20, Figure 11(d) shows the output of the delay buffer 21, Figure 11(e) shows the output of the duty cycle modulator 22, Figure 11(f) shows the output of the amplifier 28 and Figure 11(g) shows the form of the resulting pits in the master 25 and ultimately a disk format from the master 25.

When the output of the image signal transition inhibiting circuit 29 is at logic "0", representing for example a white region of the image, the signal from the data source 20 is delayed by the delay buffer by time t_1 (see Figures 11(a) to 11(d)). However, when the output of the image signal transition inhibiting circuit 29 is at logic "1", the delay buffer is "inhibited" and the data signal from the data source 20 is only delayed by t_0.

Referring to Figure 11(e), when the output of the image signal transition inhibiting circuit 29 is at logic "0", the delayed data signal from the delay buffer 21 passes through the duty cycle modulator 22 unchanged. However, where the output of the image signal transition inhibiting circuit 29 is at logic "1", the duty cycle modulator 22 is "enabled" and each delayed data pulse is extended by time $t_e - t_k$.

The output of the duty cycle modulator 22 and the output of the image signal transition inhibiting circuit 29 are applied respectively to the non-inverting and inverting inputs of the amplifier 28. The gain control elements of the amplifier 28 are arranged such when the output of the image data source is at logic "0", the amplifier 28 outputs pulses at a first voltage and when the output of the image signal transition inhibiting circuit 29 is at logic "1", the amplifier 28 outputs pulses at a second lower voltage, as shown in Figure 11(f).

The output of the laser 23 is dependent on the output of the amplifier 28. Accordingly, the master 25 is more heavily exposed when the output of the amplifier 28 is at the higher voltage than when the output of the amplifier 28 is at the lower voltage. A laser power reduction of 15% has been found to be effective for forming the shallower pits. Consequently, the pits are reduced in depth and extended in black regions of the observable image as shown in Figure 11(g).

In the present embodiment, the image signal transition inhibiting circuit 29 ensures that image data transitions do not occur during pit definition because this causes jitter due to the operation of the delay buffer 21 and the duty cycle modulator 22. However, there is no inherent problem in having image data transitions in pits and such transitions would

be acceptable, if for instance the control signal to the laser were to be calculated using a microcomputer and generated directly.

The master 25 is used to produce CD's, such as that shown in Figures 1, 2 and 3, in the conventional manner.

Referring to Figures 1 and 12, "1"s of the digital data stored on the optical disk 1 are represented by the transitions at the beginnings and ends of first, second, third and fourth pits 108a, 108b, 108c, 108d. "0"s are represented by the lack of such transitions. Accordingly, the transitions must coincide with timebase reference points 9 of a timebase frame. Thus, starting at point 10, the data represented in Figure 12 is 1011011000110....

It can be seen that the first and third pits 108a, 108c are deeper, and also wider, in their middle portions than the second and fourth pits 108b, 108d. However, all of the pits 108a, 108b, 108c, 108d extend below a decision depth 11 which is the depth that produces a reflected signal taken to be the transition between a pit and a land. In order for the decision depth to be reached at the correct time, the lead in and lead out slopes of the shallow pits 108b, 108d are arranged to have the same slope as those of the deep pits 18a, 108c.

It is the difference in the pit depths and widths that produces the observable image in the image area 7.

A mastering apparatus for an optical disk 1 as shown in Figure 12 will now be described.

Referring to Figure 13, an optical disk mastering apparatus comprises a source 120 of data signals representing, for example, music or a computer program, a delay buffer 121 connected to receive data signals from the source 120 of data signals, an image data source 122, a modulation signal generator 123 connected to receive the data signals from the source 120 of data signals, the output of the delay buffer 121 and image data signals from the image data source 122, a modulator circuit 124 coupled to receive the outputs of the delay buffer 121 and the modulation signal generator 123, a laser 125 arranged to focus a writing laser beam 126 onto a master substrate 127, and a drive system 128 for

rotating the master substrate 127 and outputting a tacho signal to the image data source 122.

The image data source 122 is the same as that shown in Figure 7.

Referring to Figure 14, the delay buffer 121 has at its core a D-type flip-flop 130. The clock signal for the flip-flop 130 is generated from the input data signal by first to fifth inverters 131, 132, 133, 134, 135, a two-input exclusive-OR gate 136, a monostable multivibrator 137, a variable resistor 138 and a first capacitor 139. The first, second and third inverters 131, 132, 133 are connected in series and the incoming data is applied first to the input of the first inverter 131. The output of the third and fourth inverters 133, 134 are connected to respective inputs of the exclusive-OR gate 136. The input of the fourth inverter 134 is connected to the node between the first and second inverters 131, 132. The fifth inverter 135 is connected to receive the output of the exclusive-OR gate 136 and its output is connected to the input of the monostable multivibrator 137. The variable resistor 138 and the first capacitor 139 set the width of the output pulses of the monostable multivibrator 137. The Q output of the monostable multivibrator 137 is connected to the clock input of the flip-flop 130.

The output of the first inverter 131 is also connected to the D input of the flip-flop 30.

As a result of extra delay introduced by the extra inverter 133 in one input path to the exclusive-OR gate 137, the exclusive-OR gate 137 outputs a short positive-going pulse each time the input data changes logic level. The short pulse is inverted by the fifth inverter 135 causing the output of the fifth inverter to approach ground, thereby triggering the monostable multivibrator 137. The negative-going edge of the pulse output by the monostable multivibrator 137 clocks the D-type flip-flop 130 so that it transfers the logic level on its D-input to its Q output.

The Q output of the flip-flop 130 is connected to one terminal of a second capacitor 141 and to the non-inverting input of a differential amplifier 142. The other terminal of the second capacitor 141 is connected to ground. The inverting input of the differential amplifier 142 is connected to the wiper of a potentiometer 143 connected between Vcc

and ground. The output of the differential amplifier 142 is connected to the input of a seventh inverter 144 via a second resistor 145. The input of the seventh inverter 144 is protected against negative voltages by a diode 146 connected between its input and ground.

The second capacitor 141, the differential amplifier 142 and the potentiometer 143 provide means for setting the mark-space ratio of the output data signal.

Referring to Figure 15, the modulation signal generator 123 comprises a four-input AND-gate and a delay circuit 151. The circuit of the delay circuit 151 is identical to the that of the delay buffer 121. The input to the delay circuit 151 is taken from the output of the delay buffer 121. The inputs to the AND-gate 150 are the outputs of the image data source 122, the source 120 of data signals, the delay buffer 121 and the delay circuit 151.

Referring to Figure 16, the modulator 124 comprises a variable-gain non-inverting amplifier 160 for amplifying the delayed data signal from the delay buffer 121, an variable-gain inverting amplifier 161 for amplifying and inverting the modulation signal and a summer 162 for summing the outputs of the amplifiers 160, 161.

The control of the laser 125 will now be described.

Referring to Figures 13 to 17, Figure 17(a) shows the output of the image data source 122, Figure 17(b) shows the output of the data source 120, Figure 17(c) shows the output of the delay buffer 121, Figure 17(d) shows the output of the delay circuit 151 of the modulation signal generator 123, Figure 17(e) shows output of the modulation signal generator 123, Figure 17(f) shows the output of the modulator 124 and Figure 11(g) shows the form of the resulting pits.

The data source 120 is delayed by the delay buffer by time t_d (see Figure 17(c)). The delayed signal is also delayed by t_d by the delay circuit 151 (see Figure 17(d)). The AND-gate 150 of the modulation signal generator 123 outputs at logic "1" when the image data signal (Figure 17(a)), the data from the source 120 of data signals (Figure 17(b), the

delayed data signal (Figure 17(c)) and the further delayed data signal (Figure 17(d)) are all at logic "1" (Figure 17(e)).

The modulator 124 performs the function $V_{out} = k_3(k_1.V_{data} - k_2.V_{mod})$ where k_1 and k_2 are constants, represented by the gains of the amplifiers 160, 161, k2 being less than k_1 and k_3 is the gain of the summer 162 for the outputs of both of the amplifiers 160, 161. It will be appreciated that the gains may be distributed differently and that the summer may have different gains for the outputs of the amplifiers 160, 161. The resulting output from the modulator 124 comprises a pulse train in which the pulses occurring when the image data signal is at logic "1" have a reduced amplitude region between higher end regions. If the image data signal changes state during a data signal pulse, the effect is merely to extend on of the higher end regions 170, depending on whether the transition is positive- or negative-going.

The output of the laser 125 is dependent on the output of the modulator 124. Accordingly, the photoresist layer on the master 127 is more heavily exposed when the output of the modulator 124 is at the higher voltage than when the output of the modulator 124 is at the lower voltage. A laser power reduction of 15% has been found to be effective for forming the shallower pits. Consequently, when the master 127 has been developed and etched, inner portions of the pits are reduced in depth in black regions of the observable image as shown in Figure 17(g).

It should be noted that if the duration of a data signal pulse is less than $2.t_d$, no lower voltage region will occur in the corresponding modulator output pulse.

The master 127 is used to produce CD's, such as that shown in Figures 1 and 12, in the conventional manner.

The laser powers required for forming deep and shallow pits will depend on the particular apparatus used and the nature of the master employed. However, generally the shallow pits should be 14% or more shallower than the deep pits, preferably 20% to 30% shallower. This degree of pit depth variation is not achievable by the prior art techniques without causing too much jitter in the data signal produced on reading the disk.

It will be appreciated that many modifications may be made to the above-described embodiments without departing from the spirit and scope of the claims. For instance, the role of the modulator 124 may be taken by a conventional laser controller by applying the modulation signal to an offset input.

The first embodiment described above is particularly, but not exclusively, adapted for the productions of optical data carriers by the non-photoresist method whereas the second embodiment is particularly, but not exclusively, adapted for the productions of optical data carriers by the photoresist method.

The present invention has been described with reference to the use of lasers for forming a master. However, the present invention is not limited thereto and other forms of beam, such as electron beams may be used to form the pits in a master.

Claims

1. An optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits has a substantially flat region whose depth is less than 86% of the depth of the pits which are not in the subset, so as to produce an observable image.

2. A data carrier according to claim 1, wherein the depth of said region is in the range 70% to 80% of the depth of the pits which are not in the subset.

3. A data carrier according to claim 1, wherein the observable image is visible to the naked eye.

4. A data carrier according to claim 1, wherein the profiles of the pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

5. A data carrier according to claim 4, wherein the pits of said subset are longer than would be the case if they were not members of the subset.

6. A data carrier according to claim 4, wherein said timebase frame is configured for constant linear velocity reading of data stored by said pits.

7. A data carrier according to claim 1, comprising a disc-shaped substrate.

8. An optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits is of lesser depth and is longer than would be the case if it were not a member of the subset.

9. A data carrier according to claim 8, wherein the observable image is visible to the naked eye.

10. A data carrier according to claim 9, wherein the profiles of the pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

11. A data carrier according to claim 10, wherein said timebase frame is configured for constant linear velocity reading of data stored by said pits.

12. A data carrier according to claim 8, comprising a disc-shaped substrate.

13. An optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, wherein each pit of a subset of the data storage pits has a substantially flat shallower intermediate region between start and end regions of greater depth.

14. A data carrier according to claim 13, wherein the depth of each said intermediate region is in the range 70% to 80% of the depth of the associated start and end regions.

15. A data carrier according to claim 13, wherein the observable image is visible to the naked eye.

16. A data carrier according to claim 13, comprising a disc-shaped substrate.

17. A master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits has a substantially flat region whose depth less than 86% of the depth of the pits which are not in the subset, so as to produce an observable image on an optical data carrier manufactured with the master.

18. A master according to claim 17, wherein the depth of each said region is in the range 70% to 80% of the depth of the pits that are not in said subset.

19. A master according to claim 17, wherein the observable image is visible to the naked eye.

20. A master according to claim 17, wherein the profiles of the data storage pit mastering pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

21. A master according to claim 20, wherein the pits of said subset are longer than would be the case if they were not members of the subset.

22. A master according to claim 20, wherein said timebase frame is configured for constant linear velocity reading of data stored by pits formed using the data storage pit mastering pits.

23. A master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits is of lesser depth and is longer than would be the case if it were not a member of the subset.

24. A master according to claim 23, wherein the observable image is visible to the naked eye.

25. A master according to claim 23, wherein the profiles of the data storage pit mastering pits in the reading direction are such that pit start and pit end reflectivity threshold points are aligned with a predetermined timebase frame.

26. A master according to claim 25, wherein said timebase frame is configured for constant linear velocity reading of data stored by data storage pits formed using said data storage pit mastering pits.

27. A master for an optically readable data carrier of a type whose reflectivity for a reading laser beam is modulated by a plurality of data storage pits, the master comprising

a plurality of data storage pit mastering pits, wherein each pit of a subset of the data storage pit mastering pits has a substantially flat shallower intermediate region between start and end regions of greater depth.

28. A master according to claim 27, wherein the depth of each said intermediate region is in the range 70% to 80% of the depth of the associated start and end regions.

29. A master according to claim 27, wherein the observable image is visible to the naked eye.

30. A master according to claim 27, comprising a disc-shaped substrate.

31. A optical data carrier mastering apparatus comprising:

a source of digital data signals;

a source of image data signals;

signal processing means for modifying a digital data signal from the source of digital data signals in dependence on an image data signal from the source of image data signals; and

a beam device responsive to the output of the signal processing means and arranged for scanning a master with a beam,

wherein the signal processing means selectively modifies the digital data signal so as to reduce the intensity of the beam during formation of pits representing both said digital data and said image data.

32. An apparatus according to claim 31, wherein the signal processing means is responsive to an image data signal from the source of image data signals to extend the duration of pits representing both said digital data and said image signals.

33. An apparatus according to claim 32, wherein the signal processing means comprises:

a variable delay for delaying digital data signals from the source of digital data signals,

a pulse extending circuit for selectively extending delayed digital data pulses output by the variable delay, and

a pulse amplitude control circuit for controlling the amplitude of digital data pulses output by the pulse extending circuit,

wherein the variable delay is responsive to image data signals at first level to introduce a first delay and to image data signals at a second level to introduce a second smaller delay, the pulse extending circuit is responsive to image data signals at said second level to extend digital data pulses, and the amplitude control circuit is responsive to image data signals being at said second level to output pulses for producing a beam of reduced intensity.

34. An apparatus according to claim 31, wherein the signal processing means is responsive to an image data signal from the source of image data signals to produce an internal region of reduced depth in pits representing both said digital data and said image signals.

35. An apparatus according to claim 34, wherein the signal processing means comprises:

a first delay for delaying digital data signals from the source of digital data signals,

a second delay for delaying delayed digital data signals output by the first delay;

an AND-gate for ANDing the outputs of the source of digital data signals, the source of image data signals, the first delay and the second delay, and

a modulator for modulating the amplitude of the output of the first delay with the output of the AND-gate to generate a driving signal for the beam device.

36. An apparatus according to claim 31, wherein the beam device comprises a laser.

37. A method of forming a master for an optical data carrier bearing an observable image, the method comprising the steps of:-

(a) providing a digital data signal;

(b) providing an image data signals

(c) modifying the digital data signal in dependence on the image data signal to produce a modified digital data signal; and

(d) irradiating a master blank in dependence on the modified digital data signal using a beam for forming a pattern of pits,

wherein pulses of the digital data signal is selectively modified so as to reduce the intensity of the beam during formation of pits representing both said digital data and said image data.

38. A method according to claim 37, wherein the digital data signal is modified so as to lengthen pits using said reduced intensity.

39. A method according to claim 37, wherein the digital data signal is modified so as to reduce the intensity of the beam only during formation of intermediate portions of pits representing both said digital data and said image data

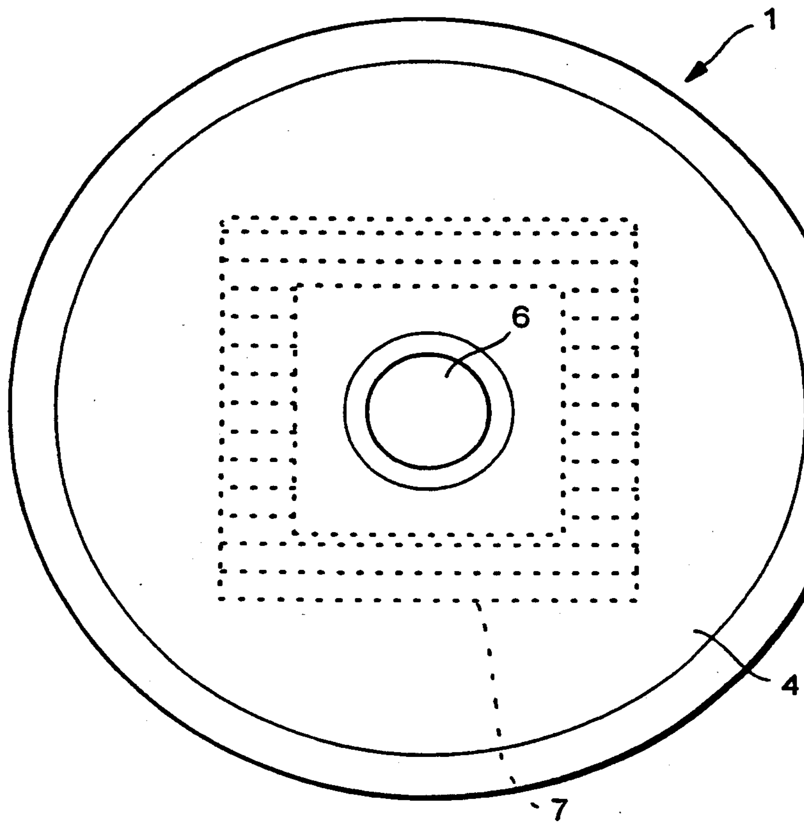

FIG. 1

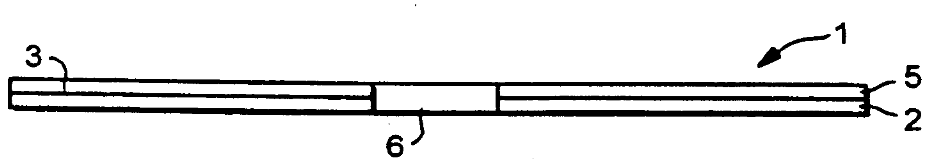

FIG. 2

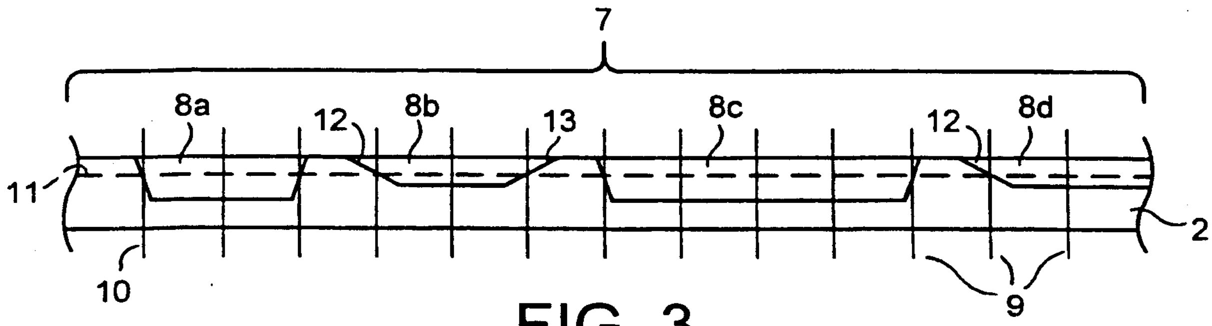
7
8a
12
8b
13
8c
12
8d
11
2
10
9

FIG. 3

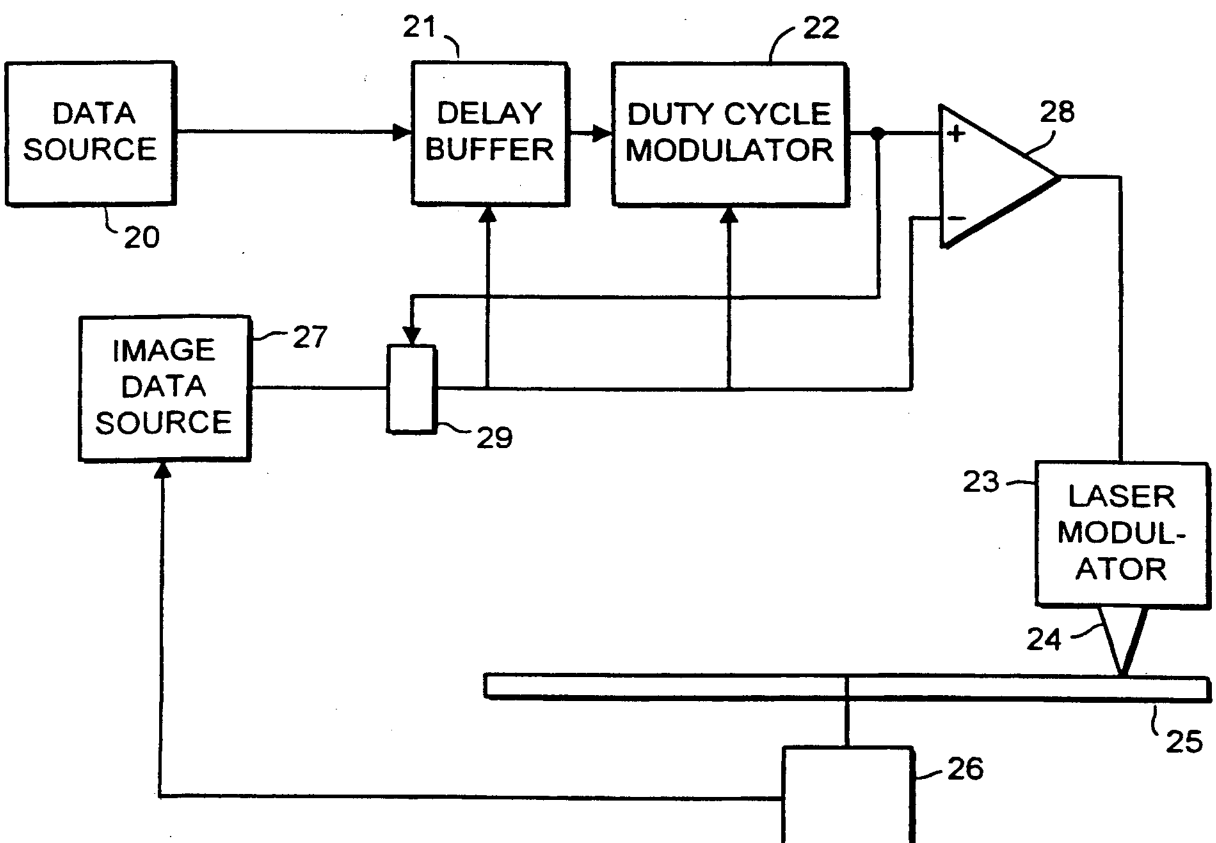
DATA SOURCE
20
21
DELAY BUFFER
22
DUTY CYCLE MODULATOR
28
+
-
IMAGE DATA SOURCE
27
29
23
LASER MODUL-ATOR
24
25
26

FIG. 4

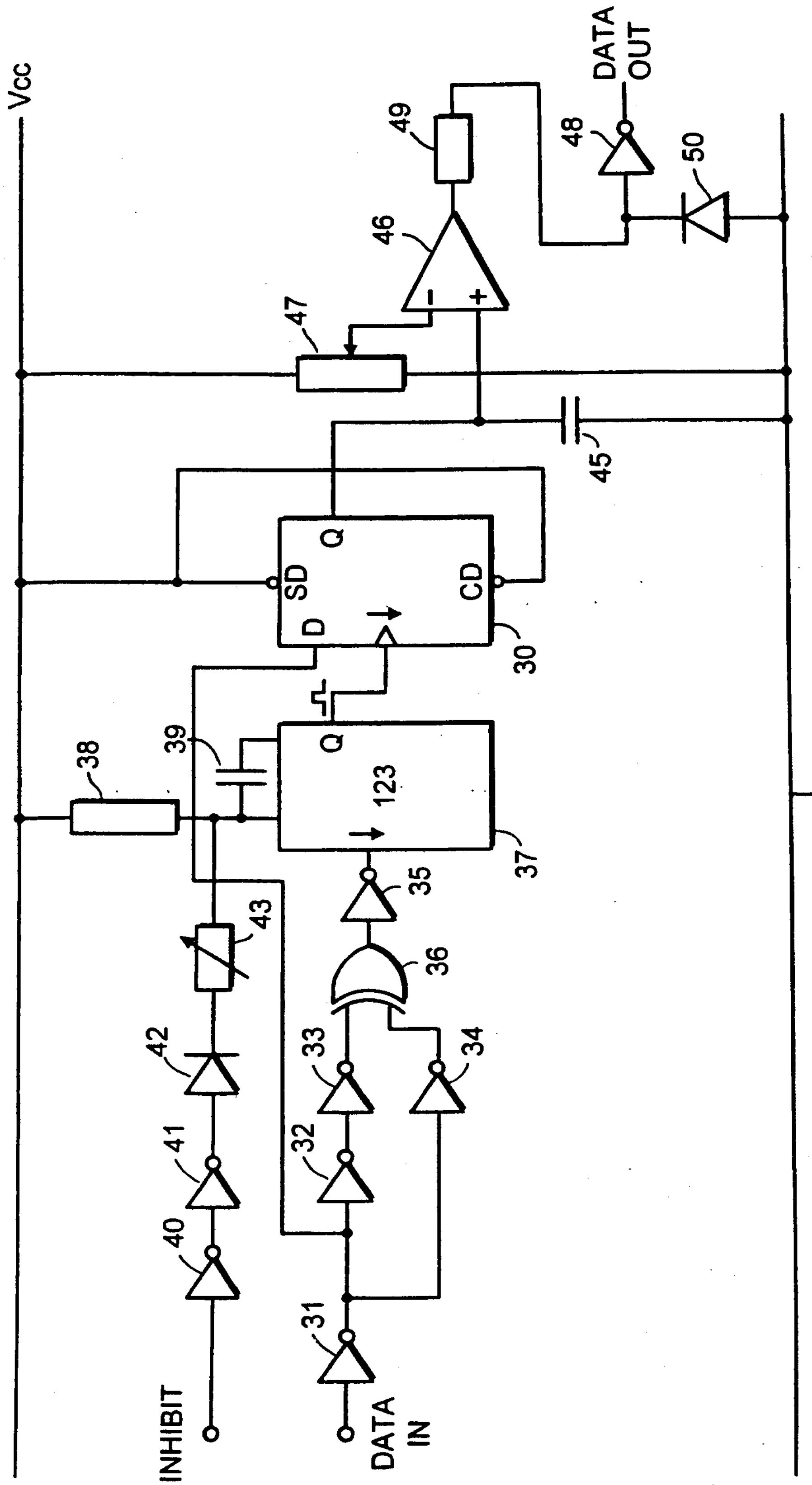
Vcc
DATA OUT
INHIBIT
DATA IN
SD
CD
D
Q
123
30
31
32
33
34
35
36
37
38
39
40
41
42
43
45
46
47
48
49
50

FIG. 5

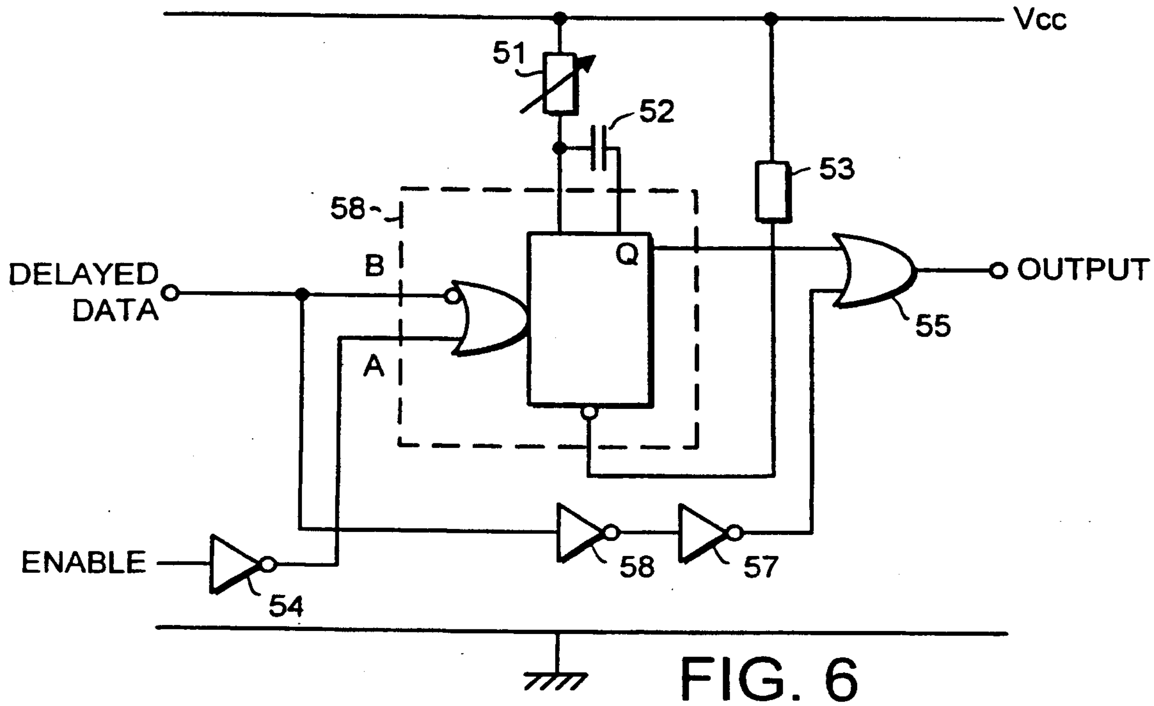
Vcc
51
52
53
58
B
Q
DELAYED
DATA
OUTPUT
A
55
ENABLE
54
58
57

FIG. 6

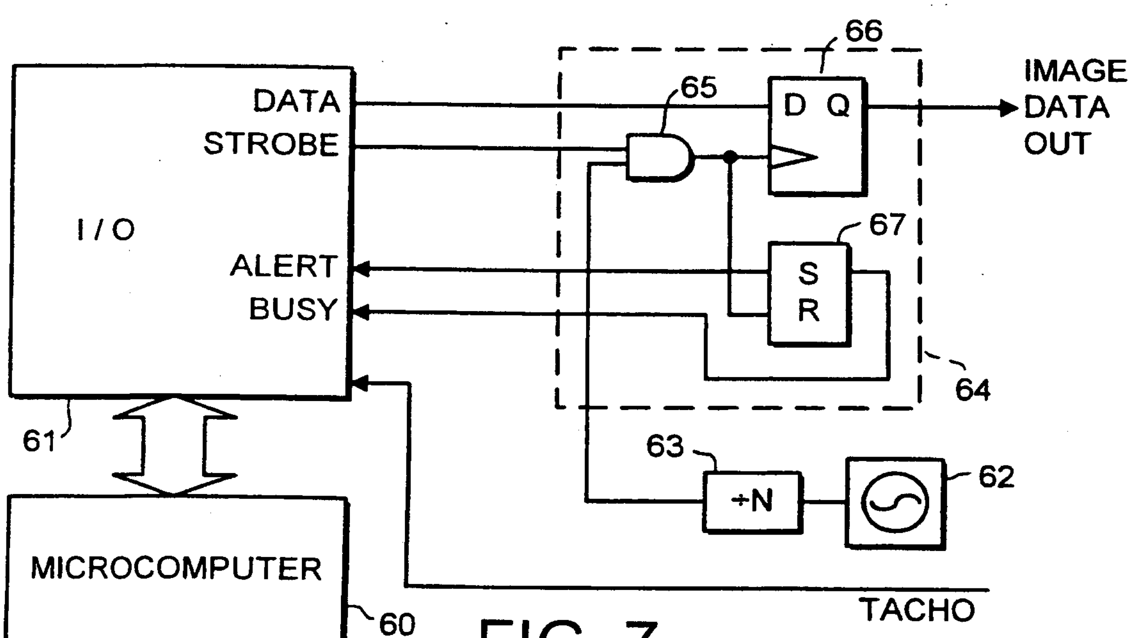
66
IMAGE
DATA
OUT
DATA
STROBE
65
D Q
I / O
67
ALERT
BUSY
S
R
64
61
63
÷N
62
MICROCOMPUTER
60
TACHO

FIG. 7

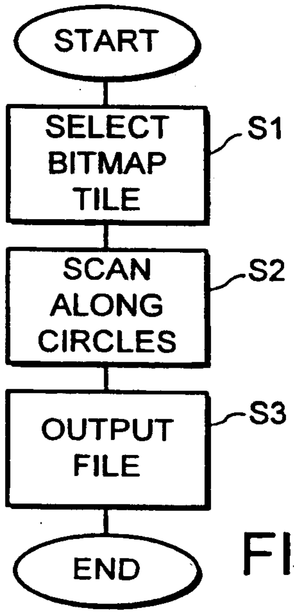
START
SELECT BITMAP TILE
S1
SCAN ALONG CIRCLES
S2
OUTPUT FILE
S3
END

FIG. 8

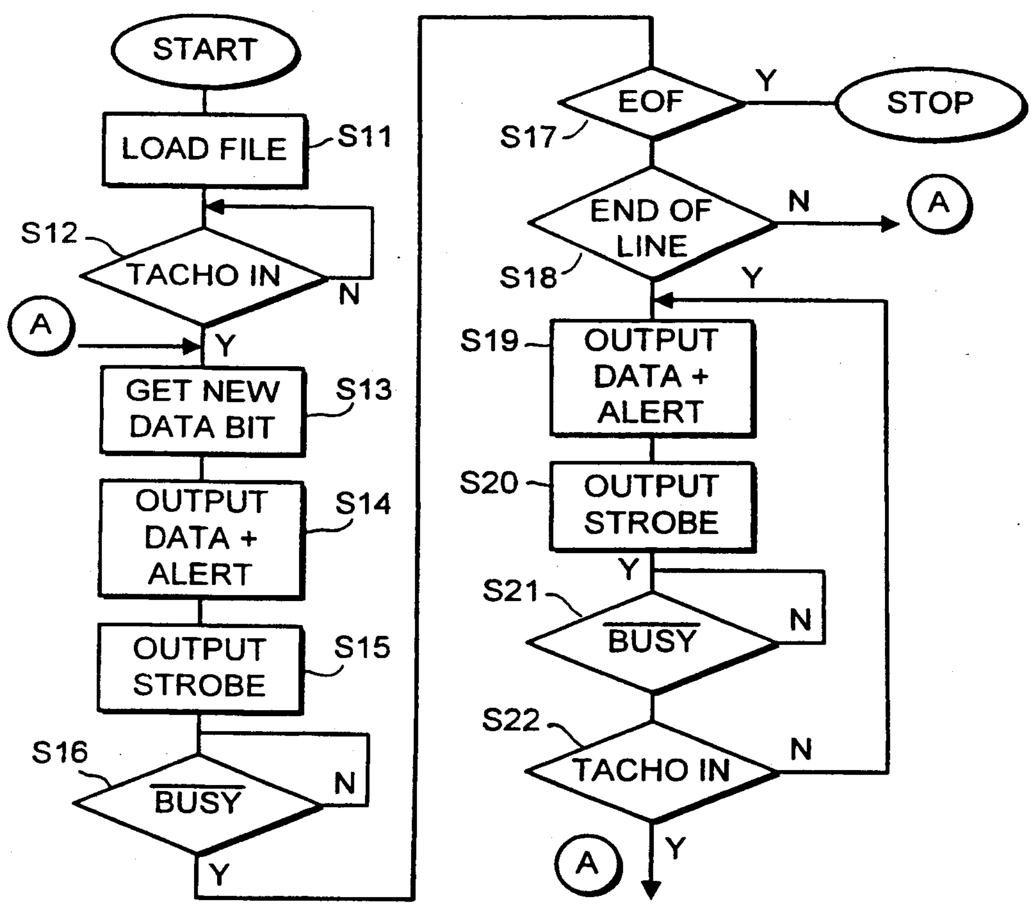
START
LOAD FILE
S11
S12
TACHO IN
N
A
Y
GET NEW DATA BIT
S13
OUTPUT DATA + ALERT
S14
OUTPUT STROBE
S15
S16
BUSY
N
Y
EOF
Y
STOP
S17
END OF LINE
N
A
S18
Y
S19
OUTPUT DATA + ALERT
S20
OUTPUT STROBE
Y
S21
BUSY
N
S22
TACHO IN
N
A
Y

FIG. 9

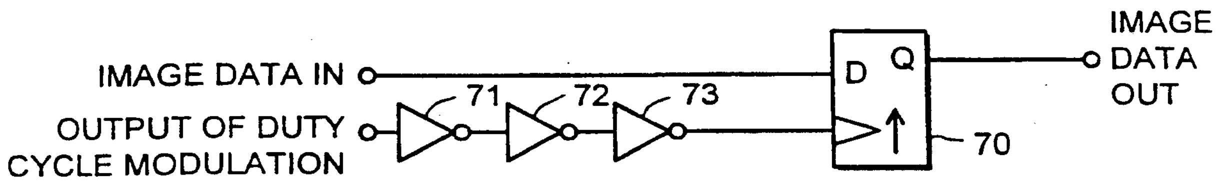
IMAGE DATA IN
OUTPUT OF DUTY CYCLE MODULATION
71
72
73
D
Q
70
IMAGE DATA OUT

FIG. 10

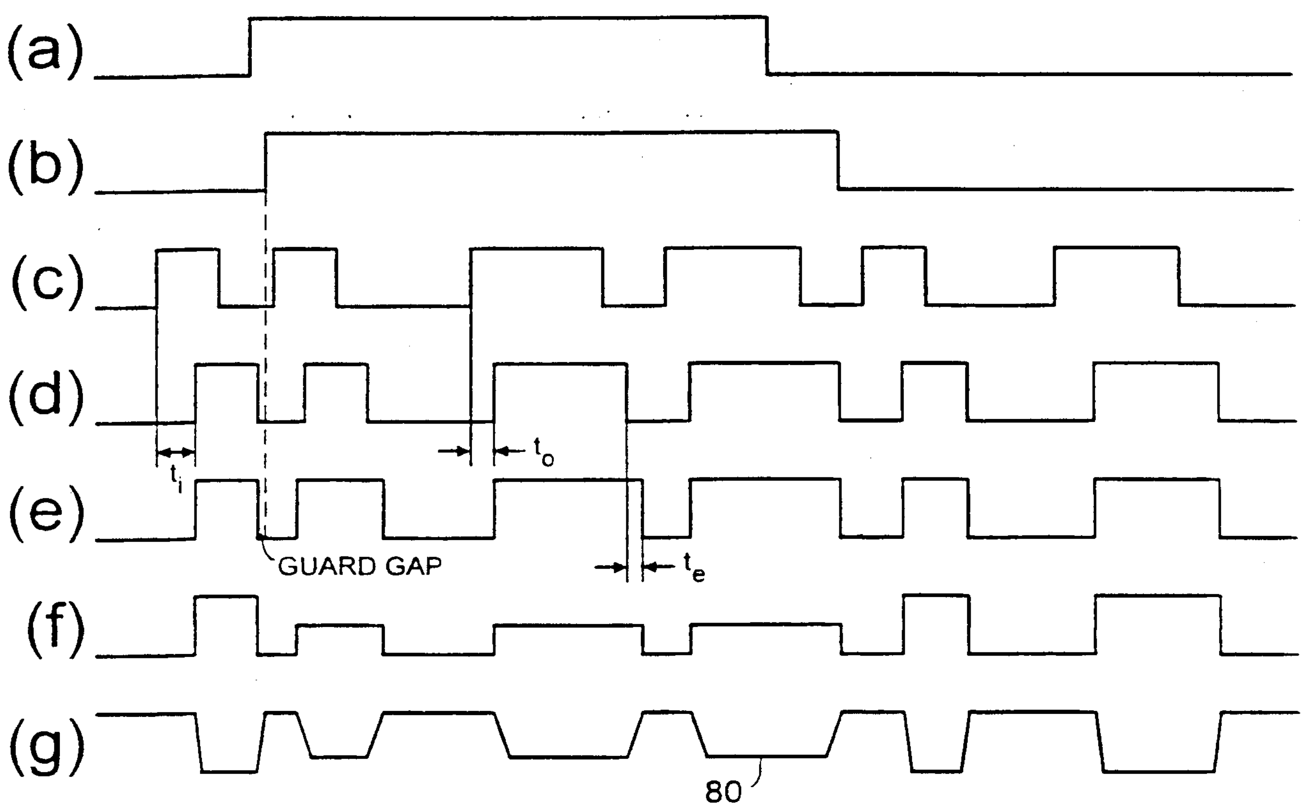
(a)
(b)
(c)
(d)
(e)
(f)
(g)
t_i
t_o
t_e
GUARD GAP
80

FIG. 11

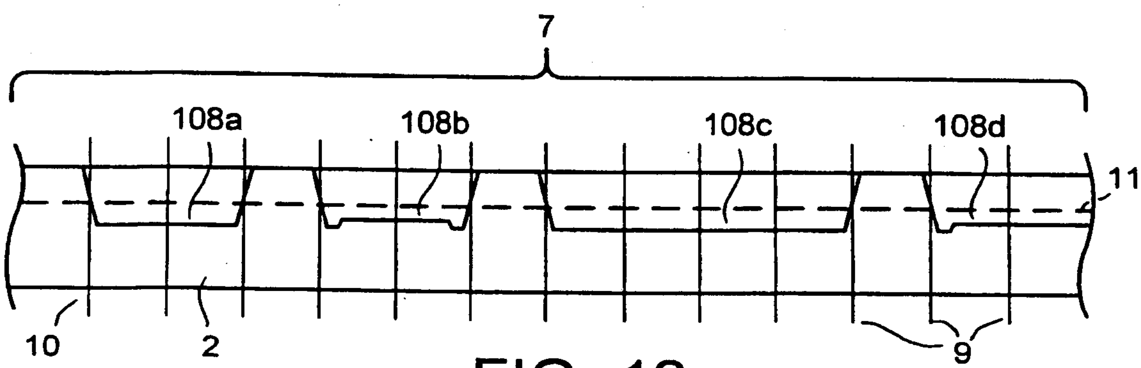
7
108a
108b
108c
108d
11
10
2
9

FIG. 12

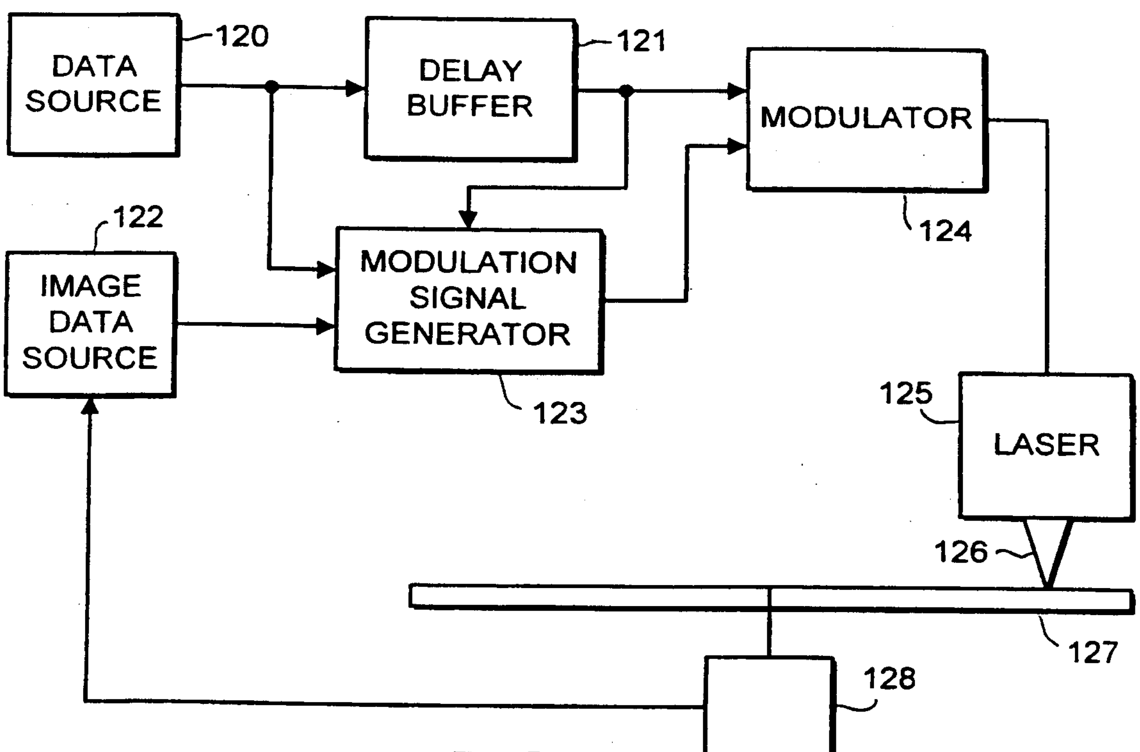
DATA SOURCE
120
DELAY BUFFER
121
MODULATOR
124
122
IMAGE DATA SOURCE
MODULATION SIGNAL GENERATOR
123
125
LASER
126
127
128

FIG. 13

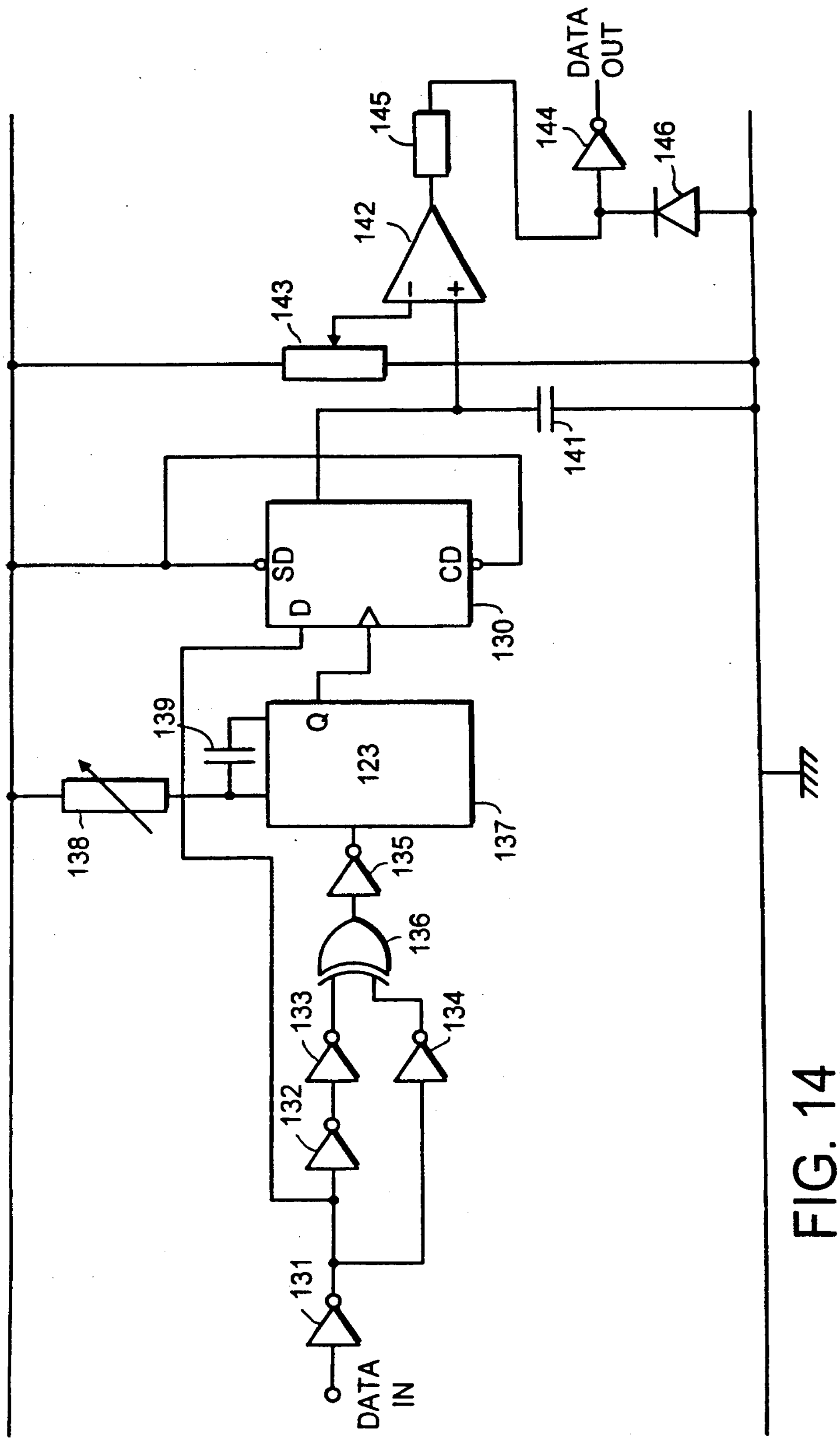
DATA OUT
145
144
146
142
143
141
130
SD
CD
D
139
Q
123
138
137
135
136
133
134
132
131
DATA IN

FIG. 14

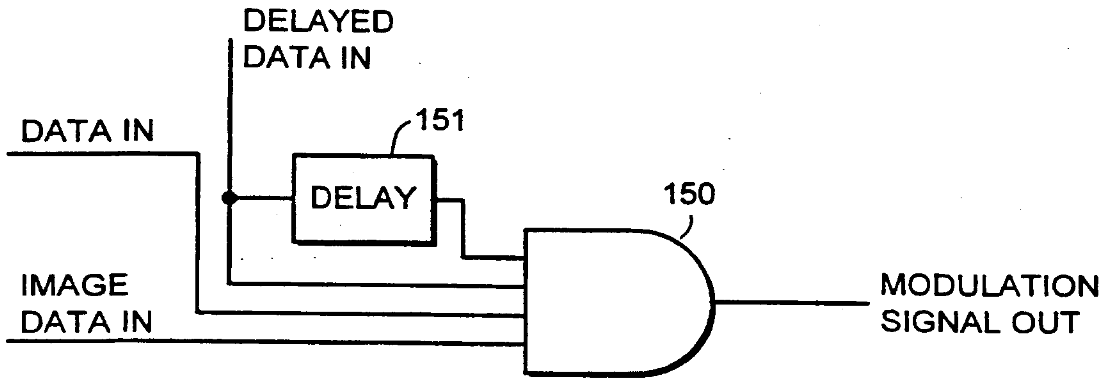
DELAYED
DATA IN
DATA IN
151
DELAY
150
IMAGE
DATA IN
MODULATION
SIGNAL OUT

FIG. 15

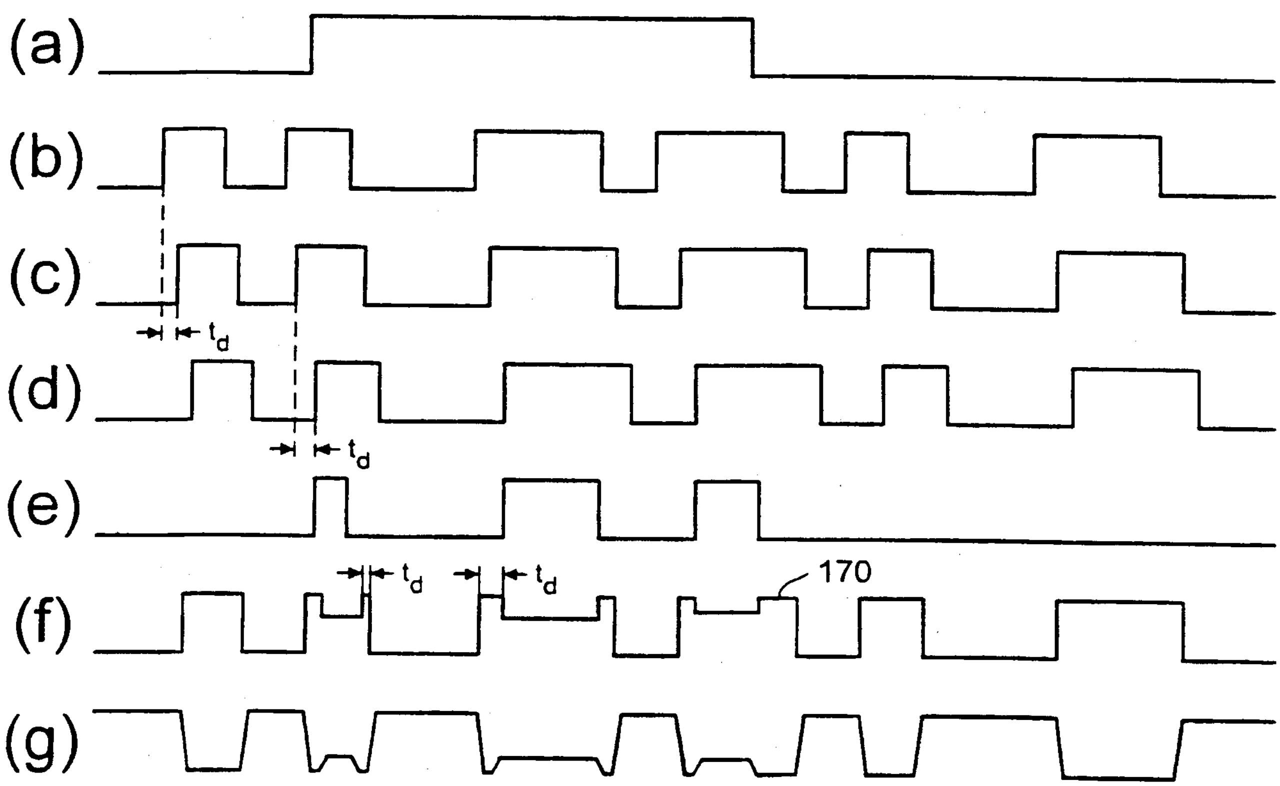
(a)
(b)
(c)
t_d
(d)
t_d
(e)
t_d
t_d
170
(f)
(g)

FIG. 17

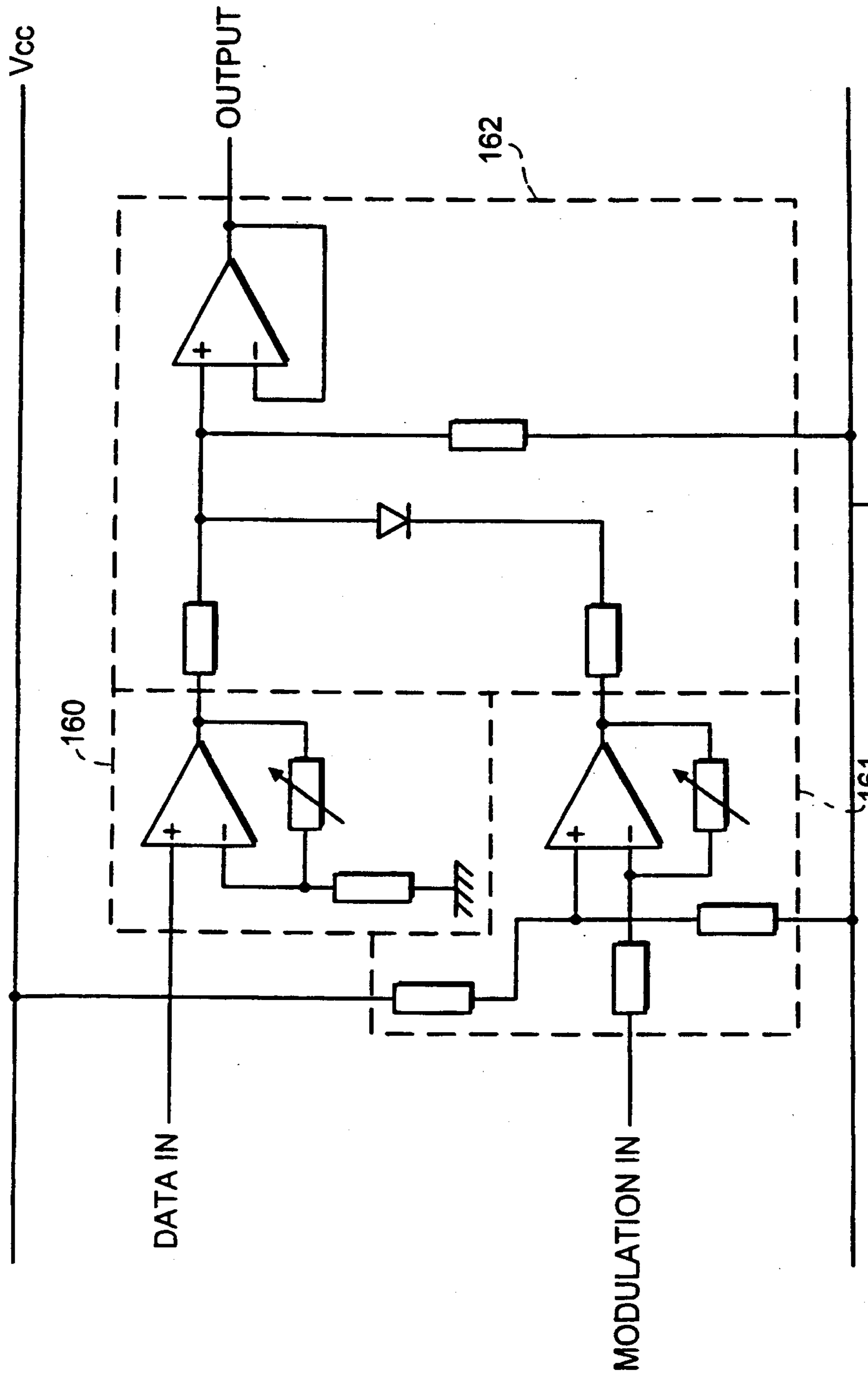

FIG. 16

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 99/01578

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B7/24 G11B7/26 G11B23/28 G11B7/013 G11B7/125

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 608 718 A (SCHIEWE HILMAR) 4 March 1997 (1997-03-04) abstract; figures 1,2 column 3, line 55 -column 4, line 53	1,3,7-9, 12,17, 19,23,24
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 13, 30 November 1999 (1999-11-30) -& JP 11 224442 A (NIPPON COLUMBIA CO LTD), 17 August 1999 (1999-08-17)	1,8
A	abstract	13,17, 23,27

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2000	29/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pariset, N

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INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/IB 99/01578

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 896 332 A (THOMSON MULTIMEDIA SA) 10 February 1999 (1999-02-10) abstract column 3, line 21 - line 57; figure 2 column 4, line 20 -column 5, line 10; figures 3,4 ---	1,8,31
A	US 5 751 690 A (MURAKAMI YUTAKA ET AL) 12 May 1998 (1998-05-12) abstract; figures 1-2C,5-6C column 2, line 31 -column 3, line 3 column 4, line 43 -column 6, line 22 ---	1-39
A	US 5 398 231 A (SHIN YUAKI ET AL) 14 March 1995 (1995-03-14) cited in the application abstract; figures 1A-2B,4,5 column 4, line 6 -column 5, line 9 column 5, line 42 - line 51 -----	1-39

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Inter   nal Application No
PCT/IB 99/01578

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